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THIS WORK CONSISTS OF THE DESIGN AND PREPARATION OF FINAL DESIGN DOCUMENTS, WITH ON-BOARD REVIEW, FOR THE CONSTRUCTION OF FACILITIES TO ELIMINATE THE MIGRATION OF CHEMICAL CONTAMINANTS THROUGH THE NORTH BOUNDARY AQUIFER CHANNEL. THE PRIMARY PURPOSE AND FUNCTION OF THIS PROJECT IS TO REDUCE CONTAMINANT LEVELS LEAVING RMA TO WITHIN APPROVED STANDARDS. FOLLOWING, IS THE GENERAL DESCRIPTION OF WORK WITH THIS DOCUMENT IS CONCERNED: PROVIDING FLUORIDE REMOVAL BUILDING, PROVIDE AN ACID STORAGE TANK & CONTAINMENT AREA, PROVIDE AN EVAPORATION BASIN, PROVIDE A TURNAROUND AREA AND DRIVEWAY AND TO PROVIDE A VALVE PIT.

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LIQUID WASTE DISPOSAL FACILITY
NORTH BOUNDARY EXPANSION
ROCKY MOUNTAIN ARSENAL

Commerce City, Colorado

FY 80

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July 1980

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CHAPTER I

INTRODUCTION

A. AUTHORITY AND SCOPE.

1. Authority. The Design Documents for the Liquid Waste Disposal Facility, North Boundary Expansion were authorized by Directive No. 14, Design 80-MCA-Omaha District, dated 16 August 1979.

2. Scope. This work consists of the design and preparation of Final Design Documents, with onboard review, for the construction of facilities to eliminate the migration of chemical contaminants through the North Boundary Aquifer Channel.

B. APPLICABLE CRITERIA.

1. General.

Appendix C with Supplement, Instructions for Contract No. DACA45-79-C-0019

2. Publications.

Department of Labor, Occupational Safety and Health Act Standards Manual

Department of the Army Technical Manual, TM 5-809-10, Seismic Design for Buildings

Department of Defense, DOD 4270.1-M, Construction Criteria Manual

Department of the Army Technical Manual, TM 5-822-2, General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas

Department of the Army Technical Manual, TM 5-820-3, Drainage and Erosion-Control Structures for Airfields and Heliports

Department of the Army Technical Manual, TM 5-820-4, Drainage for Areas other than Airfields

Department of the Army Technical Manual, TM 5-810-5, Plumbing

National Electrical Code NFPA No. 70

Life Safety Code NFPA No. 101

National Electrical Safety Code

C. PURPOSE AND FUNCTION. The primary purpose and function of this project is to reduce contaminant levels leaving Rocky Mountain Arsenal to within approved standards. These contaminants are leaking from storage basins, entering the subsurface soil and water table, and in some cases are being transported across the Arsenal boundaries by ground water.

D. GENERAL DESCRIPTION OF WORK.

1. Provide fluoride removal building to be interfaced with the existing carbon treatment building.

2. Provide an acid storage tank and containment area.

3. Provide an evaporation basin.

4. Provide a turnaround area and driveway in conjunction with the new fluoride removal building.

5. Provide a valve pit adjacent to the effluent wet well.

CHAPTER II

ARCHITECTURAL

A. GENERAL

This will be a new pre-engineered clearspan low rigid frame insulated metal building approximately 80 feet wide and 104 feet long, erected to serve as a processing building and laboratory. The building components will be interlocking rib panels, flashing, trim, closure strips and other accessories to provide a waterproof structure.

The exterior walls will have personnel doors, sliding insulated glass windows and rollup delivery door providing access and natural ventilation. Continuous gravity roof ventilators at the ridge will provide natural gravity ventilation.

The laboratory walls and ceiling will be insulated and sheathed on each side with two layers of gypsum wallboard for sound control from the processing equipment. A large sound insulated window will provide visual review of equipment operations. Access to the laboratory will be provided from the processing room with a sound insulating door and natural light and ventilation will be provided with an exterior sliding window unit. why lab?

CHAPTER III

STRUCTURAL

A. SCOPE OF WORK. A listing of references applicable to this section is found in the introduction to this Design Analysis. Recommended structures to be provided by this project include the following:

1. Foundation slab and footings for the fluoride removal building
2. Equipment foundations and reinforced concrete basins within the fluoride removal building.
3. Acid storage tank foundation and containment wall.
4. Reinforced concrete evaporation basin.
5. Reinforced concrete valve pit.

The design information listed in this section is applicable to all structures.

B. FOUNDATION DESIGN DATA.

1. Depth. A minimum depth of 3.5 feet below final grade was used for all foundations to protect against frost damage.

2. Bearing pressures. Footings were sized for a maximum allowable soil bearing pressure of 1,400 pounds per square foot.

3. Earth pressures. For design of walls below final grade, an at rest earth pressure was used.

C. DESIGN LOADS.

1. Roof live load, 30 psf.

2. Floor live load

   a. Slab on grade, greater of equipment load or 250 psf.

b. Suspended slab, 100 psf plus equipment load.

3. Wind load, 25 psf.

4. Seismic, Zone 1, Z = 0.25 designed in accordance with TM 5-809-10. ?

D. FLOOR SLABS.

1. Slab on grade over 6-inch layer of capillary water barrier.

2. Structural floor, concrete slab.

E. MATERIALS.

1. Concrete.

a. Class AA, 4000 psi compressive strength at 28 days for portions of structure containing liquids.

b. Class A, 3000 psi compressive strength at 28 days for all concrete not otherwise noted.

c. Reinforcement, ASTM A 615 or ASTM A 617. Ties and stirrups, Grade 40; all others Grade 60.

F. VIBRATION. The only mechanical equipment which will be installed on the structures are pumps and motors. Vibrations produced by this equipment will be readily absorbed by the concrete structure without any adverse effects. Isolation of the equipment from the structure is not required.

G. ALTERNATIVES. There are no structural systems competitive with reinforced concrete for the facilities included in this project.

CHAPTER IV

MECHANICAL

A. CRITERIA LISTING.

1. Publications.

Department of Defense Manual, DOD 4270.1-M, Construction Criteria Manual

Department of the Army, TM 5-810-1, Mechanical Design-Heating, Ventilating, and Air Conditioning

Department of the Army, TM 5-810-5, Plumbing

Department of the Army, TM 5-810-6, Mechanical Design - Gas Fitting

Department of the Army, TM 5-785, Engineering Weather Data

Project Development Brochure, Rocky Mountain Arsenal, Liquid Waste Disposal Facility, North Boundary Expansion, Revised 31 July 1979

U.S. Army Engineer Waterways Experiment Station, Engineering and Construction Materials Compatibility Study

Minutes of Review Meetings of February 14 and 15, 1980, February 28 and 29, 1980, and April 29, 1980

B. PLUMBING.

1. System Description.

a. Potable water is not available at this site and there will be no sanitary drain and waste system. A nonpotable floor washdown system, including hose faucets, floor drains, an unvented drain system and a duplex sump pump will be supplied. Two emergency showers will be provided.

Water supply for the washdown system, laboratory, and emergency showers will be provided from the plant influent pump discharge. Although this water is considered nonpotable, it has been filtered and treated to remove organic contaminants. Signs will be provided at each outlet to warn personnel that the water is unsafe for human consumption.

The drain system will consist of floor drains installed in the pipe trenches to collect washdown water and convey it to a duplex sump pump from which it will be delivered to the sedimentation basin, the plant influent wet well, or to the organic treatment plant sludge pump. Since this is an open drain system with no biological waste present, both traps and vents have been eliminated.

An acid waste collection and drain system is included to handle acid wastes from the laboratory and from any spills that may occur. An acid-resistant sump pump is provided as a part of the process equipment. Discharge from the acid sump pump is piped to the sedimentation basin through acid-resisting drain pipe.

One emergency shower will be located outside of the building adjacent to the caustic soda and calcium chloride unloading stations; the other will be located inside the building adjacent to the chemical feed pumps. The exterior shower will be wall-mounted with the valve inside the building for freeze protection. The interior shower will also have an eye and facewash fountain. Water supply for the emergency showers will be from the plant influent line, and will include a bladder type, pneumatic tank which will provide both a water supply and pressure necessary to operate the showers when the process pumps may not operate. The pneumatic tank will be charged to 10 psig initially and will develop approximately 40

psig when full of water. The tank will hold 160 gallons of water or enough for approximately four minutes of shower flow.

Final connection will be made to a gas-fired, self-contained toilet and a laboratory sink, both of which will be furnished by the general contractor as equipment.

2. Equipment and Fixtures.

Sump Pump:	39 gpm at 15-foot head Aurora Model 522A Buffalo Model 905A-AB6 Paco Model SL 1570-0
Emergency Shower:	Speakman Model SE-242 (Outside) Speakman Model SE-607 (Inside) Haws Model 8111-FP (Outside) Haws Model 8346 (Inside)

C. HEATING.

1. Design Conditions.

	Inside	Outside
Summer	101 degrees FDB	91 degrees FDB
Winter	68 degrees FDB	-5 degrees FDB

why higher inside during summer - lab area cooled via heat pump below.

2. System Description.

a. Building heat will be provided by two LP gas-fired unit heaters of 192 MBh capacity. Control will be by wall-mounted thermostats.

b. The laboratory area will be heated and cooled by a through-wall unitary heat pump of 8479 Btuh cooling capacity and 8960 Btuh heating capacity.

C. SOLAR HEATING SYSTEMS have been analyzed by use of the SOLCOST program, a computerized simulation and optimization procedure for solar collector systems. The program analyzes the economics of several systems of differing collector area, and selects the optimum economic system. In this case,

the program selected the system with the least area because that system exhibits the least negative return an investment. However, the procedures mandated by ETL 1110-3-302 show that <u>any</u> solar heating system is economically feasible, with the optimum area providing approximately 64 percent of the heating requirement. The optimum system, as determined by ETL 1110-3-302 has 2,496 square feet of collector area and an estimated cost of $124,812. Calculations are included in the calculations volume.

what does this say? will it be used or not

3. <u>Equipment</u>.

Unit Heaters:	Trane Model GPAB02200B Modine Model PA225 Dunham Bush Model W225
Heat Pump:	General Electric Model A2B588D*AL American Air Filter Model SCAC-1-109

CHAPTER V

ELECTRICAL

A. GENERAL. This design is based on, but not limited to, the applicable publications, codes, and specifications listed in the introduction to this narrative.

B. SCOPE. This design will generally consist of the following details:

1. Interior.

   a. Illumination

   b. Raceway systems and conductors

   c. Motor Control Center

   d. Panelboards

2. Exterior.

   a. Primary service

   b. Transformers

   c. Security lighting

   d. Lightning protection

3. Controls and Instrumentation.

   a. Control consoles, plant flow panel, Motor Control Center

   b. Variable-speed pumps

   c. Flow rate sensors

   d. Regeneration controls

   e. Sludge controls

   f. Filters

   g. Chemical feed pumps

h. Fluoride monitor

i. pH monitor

C. INTERIOR.

1. The design footcandle level is 50 footcandles in the laboratory and 30 footcandles in the process area. The average maintained illumination is calculated to be 54 footcandles in the laboratory and 34 footcandles in the process area. Lighting fixtures provided in the laboratory are prismatic wraparound fixtures with 2F40 cool white fluorescent bulbs. Lighting fixtures used in the process area are 150 watt low bay high pressure sodium fixtures with a refractor concealing the arc tube. The fixtures are enclosed and gasketed. One switch will be installed at the east door for each circuit of process area lighting. One switch will be installed in the laboratory to control the lighting there. Several of the above high pressure sodium fixtures will be provided with quartz standby lights to provide illumination until the arc tube becomes warm. Emergency battery pack lighting is provided along with illuminated battery pack exit lights at each exit. Voltage will be 277 volts.

2. Receptacles will be provided in six locations for general purpose loads in the process area. These receptacles will be 20 amperes, 120 volt, duplex weatherproof type. A 20-ampere 240-volt receptacle will be provided in the laboratory for the heat pump. Seven 20-amperes, 120-volt duplex receptacles will be provided in the laboratory.

3. Conduit system will be rigid aluminum or zinc-coated steel.

4. Conductors will be copper or aluminum with insulation conforming to the NEC. Conductors will be installed in dry locations, damp locations, and underground.

5. Motor Control Center will serve as service entrance equipment. The service disconnecting means will be a 600 ampere circuit breaker. The Motor Control Center will contain starters for all pumps 2 horsepower and above except for the influent pumps and air compressor. Provisions will be made for adding two additional Motor Control Center sections in the future. why?

6. Reduced voltage starters will be provided for all motor 50 horsepower and above.

7. Panelboards installed will be circuit breaker type.

8. Transformers of the dry type will be used to provide 240/120 volt from a 480-volt source.

D. EXTERIOR

1. Primary service to the exisdting building is 13.2 kV, 3-phase, 4 wire. The transformers are three 50 kVA, single-phase transformers which provide 13.2 kV -480Y/277 volt service.

2. A three-phase 500 kVA transformer pad-mounted will provide 13.2 kV -480Y/277 volt service to both buildings. The existing transformers will remain the property of the Government.

3. Service to the buildings will be underground.

4. Security lighting will be provided around the fluoride treatment building by 150 W high pressure sodium wallpack fixtures.

5. Lightning protection will be provided. Building steel will be made electrically continuous and grounded. Lightning rods will be installed.

E. CONTROLS AND INSTRUMENTATION.

1. Controls and instrumentation for the fluoride removal process are primarily located in the Control Console. The Control Console comprises Hand-Off-Auto switches for most pump motors, indicator lights, indicators, recorders, and control circuitry for regeneration of the alumina column. A Plant Flow Panel stands next to the Control Console, providing the operator with annunciator lights for all significant equipment, superimposed on a functional schematic of the plant. The Motor Control Center houses motor starters, disconnects, thermal overloads, and annunciator lights for most integral horsepower motors. A Filter Control Console is provided in a freestanding enclosure, which houses the control switches and indicators for the two high pressure filters. Local On/Off controls are provided for most motors to allow local shutoff of motors for maintenance.

2. Three pumps located in the influent well supply water to the alumina columns for fluoride removal. Each pump is powered from a solid state variable-frequency motor controller, which controls the speed of the pump motors. A constant level is maintained in the influent wet well by altering the pump speeds to match the rate of influent water. A bubbler tube level control cabinet is located next to the influent wet well, along with the three variable-speed motor controllers. The Control Console and the bubbler tube equipment cycle the pumps off and on, and vary the pump speeds, in response to changing influent rates.

3. The flow rate of water through each of the alumina columns is indicated, totalized, and recorded at the Control Console. Flow rate is sensed by detecting the pressure drop across flow tubes and electronically transmitting to the control console, where the signal is linearized and recorded. Flow rate is also sensed on the bypass line column backwash influent, the plant effluent, the column regeneration line, and the backwash lines in the high pressure filters.

4. Regeneration of the alumina columns is executed by control circuitry within the Control Console. The circuitry controls, all automatic valves, motors, etc., for the eight steps required for regeneration. Timers mounted in the Control Console time six of the eight steps. One of two backwash pumps located in the influent wetwell is started to begin Step 1, column backwash. Flow is directed through the desired column by pinch valves. These valves are opened or closed by compressed air, which is supplied in turn by three-way solenoid valves controlled by the Control Console. All solenoid valves are located on a solenoid valve panel, mounted adjacent to the alumina columns. Step 2 is initiated by starting one of three regeneration pumps located in the effluent wet well. The control circuity starts the pump, routes the flow through two water softeners, starts an acid pump to alter the pH, and diverts the flow through the desired column and into the precipitation basin. The sludge pumps serving the precipitation basin are automatically started. Step 3 is identical to Step 2, except that two of the three regeneration pumps are started, and the water softeners are placed in the parallel mode.

Step 4 consists of draining the column into the chemical sump. A level switch in the column tells the controls when the step is complete. Steps 5 and 6 start one and two of the regeneration pumps, respectively, route the flow through the water softeners, activate a caustic soda pump, divert the flow through a column and into the precipitation basin on the rinse holding basin. Step 7, column drain, is identical to Step. 4. Step 8 starts one regeneration pump, routes the flow bypassing the water softeners through the column, and into the rinse holding basin.

Each step in the regeneration is manually initiated by an operation from the Control Console. Steps 3 and 6 may be automatically started at the conclusion of Steps 2 and 5, if the operator desires. The regeneration pumps are interlocked to automatically start additional pumps if one or two of the pumps is out of service.

5. <u>The sludge pumps</u> in the precipitation basin remove the sludge from the basin. Polymer metering pumps and polymer mixers process the sludge to a desired consistency. The polymer metering pumps and mixers are controlled locally and not from the Control Console. The sludge scraper and the rapid mixers are mounted above the precipitation basin. The sludge scraper is provided with torque overload alarms and shutoffs. The rapid mixers are provided with reduced-voltage starters due to their large horsepower rating.

6. <u>The high pressure filters</u> are controlled from the Filter Control Console, located adjacent to the filters. Two filter backwash pumps located in the effluent wet well are controlled from the console to effect backwashing of the filter. Two filter pumps are mounted adjacent to the filters. These pumps, along with the filter backwash

pumps, are controlled from the Filter Control Console. Automatic valves within the filter package control the mode of filter operation. Filter status is annunciated on the Plant Flow Panel.

7. Chemical feed pumps are all located together next to the chemical storage tanks. The chemical pumps are locally controlled, rather than from the Control Console. Some of the chemical pumps are automatically started by the regeneration circuitry and the motor controllers for the recharge pumps, housed in a nearby building.

8. A fluoride monitor is provided on the plant effluent line; the fluoride level is electronically transmitted to the Control Console, where it is indicated and recorded.

9. pH monitors are installed on the plant effluent line, the column regeneration line, and the column influent line. pH levels are indicated locally and are also transmitted to the Control Console, where they are indicated and recorded.

CHAPTER VI

CONTAMINATED WATER TREATMENT

A. DESIGN CONDITIONS.

1. Flow. Several studies and estimates have been made of the quantity of water which will be intercepted by the existing barrier and the proposed extension. Earlier estimates placed the flow in the range of 400 to 600 gpm. The most recent estimate, done by Earth Science Associates (ESA) for this project, agrees with the earlier estimates. Rocky Mountain Arsenal (RMA) estimates showed that if all wells west of D Street were manifolded together and treated for fluoride, the wells east of D Street would contain about 2.3 mg/l fluoride, which would meet state discharge requirements. Manifolding of these low-fluoride wells would produce a flow of approximately 450 gpm. Manifolding of the remaining wells would produce a flow of approximately 150 gpm which would require treatment for the removal of excess fluoride. Therefore, based on RMA recommendations and a COE directive, the fluoride removal system is designed for an average flow of 150 gpm and a maximum flow of 450 gpm.

2. Raw Water Quality. Data are available on a number of constituents in the ground water at Rocky Mountain Arsenal. The principal contaminant of interest for the design of the facilities is fluoride. (RMA is handling expansion of granular activated carbon organic removal facilities.) Fluoride levels along the North Boundary range from less than 2 mg/l to about 5 mg/l. Several estimates have been made to determine the fluoride concentration in the water pumped from the expanded

system. The USATHAMA and Zebell (USAEWES) estimates place the fluoride concentration in the 2 to 3 mg/l range. RMA estimates indicate that if the wells west of D Street with high fluoride levels are treated, the 150 gpm flow from these wells would contain about 3.7 mg/l of fluoride. The remaining flow of 450 gpm should contain about 2.3 mg/l fluoride, and, therefore, would meet the discharge requirements. Due to the uncertainty of the actual fluoride level that will result when all the wells are operational, and the variability of the fluoride concentrations after pumping begins, the A-E recommends that the design of the fluoride removal system be based on treatment of all the boundary well water. This would ensure that the fluoride level of the water returned to the aquifer would be less than the state requirement of 2.4 mg/l. However, based on RMA recommendations and a COE directive, the design is based on a fluoride removal system to treat 150 gpm at a fluoride level of 3.7 mg/l. The design is capable of treating a peak flow of 450 gpm by permitting slipstreaming a portion of the 450 gpm GAC effluent to produce a treated water containing 2.2 mg/l of fluoride.

Another constituent which has caused concern is arsenic. The Rubel and Hager pilot plant study shows that there is no arsenic "poisoning" of the activated alumina by the water presently being pumped. The water samples were analyzed for arsenic to confirm that a "poisoning" problem did not occur.

3. Effluent Quality. The effluent limit for fluoride is 2.4 mg/l as established by a letter from the State of Colorado Department of Health to the Commander, RMA, dated 2 August 1979.

B. FLUORIDE REMOVAL.

1. Alternative Processes. The processes evaluated for the removal of fluoride were ion exchange, lime softening, bone char adsorption, and activated alumina adsorption.

In the ion exchange process, resin selectivity is dependent upon the ionic charge, and size, and solution concentration of the ions to be adsorbed. For a series of monovalent ions, the order of selectivity for exchange is shown below in decreasing order:

$$CNS^- \quad ClO_4^- \quad I^- \quad NO_3^- \quad Br^- \quad CN^- \quad HSO_4^-$$

$$NO_2^- \quad Cl^- \quad HCO_3^- \quad OH^- \quad F^-$$

On the basis of this selectivity series, removal of F^- cannot be fully achieved because fluoride ions are the last to be selectively adsorbed by resins. Therefore, the use of ion exchange resins for defluoridation is not feasible because of low media selectively for fluoride.

In lime softening, fluoride is removed by coprecipitating calcium fluoride and magnesium hydroxide. Softening normally requires a comparatively large area and significant amounts of chemicals, and the process generates large volumes of waste sludge. The high costs and anticipated sludge disposal problems eliminate lime softening as a feasible treatment process for fluoride removal.

The process most commonly used for fluoride removal is adsorption by either bone char or activated alumina. After repeated regeneration, bone char will permanently lose its fluoride adsorption capacity and must be replaced. Therefore, bone char was not considered further.

Activated alumina, however, retains its exchange capacity almost indefinitely. On the basis of fluoride removal efficiency, process reliability, and low space requirements, the activated alumina adsorption process was selected.

Activated alumina is calcined granules of hydrated alumina which have affinity for adsorbing impurities from liquids without any change of form or properties. Activated alumina is nontoxic and does not swell, soften, or disintegrate when immersed in water. High resistance to shock and abrasion are two of its important physical characteristics. It has a loose bulk density of 52 lb/ft^3 and a packed density of 55 lb/ft^3.

2. <u>Selected Process</u>. In determining the activated alumina process design basis, the following factors were considered.

Hydraulic loading

pH control of raw water

Retention time based on superficial velocity

Depth and diameter of bed

Flow configuration

Regeneration procedures

The pilot plant used by Rubel and Hager to evaluate the removal of excess fluoride from the granular activated carbon (GAC) effluent was operated at flows of 5 gpm/ft^2 and 4 gpm/ft^2. The design criteria in the final report (1) of their study proposed 7 gpm/ft^2 as a maximum flow rate. Other studies (2) have used flow rates ranging from 0.4 to 2.4 gpm/ft^2. After discussions with Messrs. Fred Rubel and Doug Thompson of Waterway Experiment Station it was concluded that the design flow should

be 5 gpm/ft^2, with a maximum flow of 7 gpm/ft^2. These loading rates establish an average superficial velocity of 0.67 ft/min and a maximum velocity of 0.95 ft/min. Grade F-1 activated alumina with 28 to 48 mesh was used in the pilot plant study and is specified for the full-scale design.

The Rubel and Hager final report showed that the activated alumina column capacity for fluoride removal was increased by a factor of three when the pH of the GAC effluent was maintained at 5.5 as compared with the removal capacity with no pH adjustment. An economic evaluation in this report showed that the cost of removing fluoride from the RMA water using pH adjustment of the GAC effluent was about one-half the cost of removing fluoride without adjusting the pH. Therefore, the design includes pH control facilities using sulfuric acid (H_2SO_4) to reduce the pH of the activiated alumina column influent to 5.5.

The final report of the pilot plant studies recommends 5 minutes minimum retention time through the column beds, based on the superficial velocity. After discussions with Mr. Rubel, the minimum superficial retention time of the full scale bed was set at 5.0 minutes. Based on the superficial velocity of 0.95 ft/min and a retention time of 5.0 minutes, the activated alumina bed depth is 5.0 feet.

Flow configurations considered included various combinations of columns both in series and in parallel and using either GAC effluent bypass or passing all GAC effluent through the alumina beds. The final design is based on RMA's concept of treating 150 gpm of high fluoride GAC effluent, which has been separated from the other well water by selective manifolding. The carbon column was designed to treat 150 gpm

at a fluoride concentration of 3.7 mg/l. Regeneration of the activated alumina columns results in a water containing fluoride that will be recycled to the activated alumina column system over a four day period; this increases the fluoride concentration of the water to be treated to 4.8 mg/l. Using a single column, the run time would be less than four days before regeneration is required. This regeneration interval would not permit adequate time for disposal of the regenerant waste as required by the selected disposal alternative (Section VI-C). Therefore, two columns are operated in parallel in a "staggered-exhaustion" mode to provide sufficient regenerant waste disposal time. During regeneration of one of the columns, all flow is passed through the second column. The operation and flows for this system to treat 150 gpm GAC effluent are shown in Table VI-3.

It is possible that ground water characteristics could change and it would be necessary to treat more than 150 gpm of high fluoride water. RMA estimates that 450 gpm is the maximum amount of water that would require treatment for fluoride. Therefore, the columns were also evaluated to determine the operating procedures necessary to treat 450 gpm. It was determined that three columns would be required instead of two and a fraction of the untreated water would be slipstreamed to produce a blended effluent water with 2.2 mg/l of fluoride. Two columns would operate in parallel to treat a portion of the 450 gpm. GAC plant effluent flow and the remainder of the flow would be bypassed and blended with alumina column effluent. The third column would be regenerated and stored for use when one of the online columns requires regeneration. The two columns are regenerated, one at a time, on two consecutive days

with the first column regeneration wastes stored to be treated together with those from the second column. This operation is shown in Table VI-4. Water from the treatment of the regeneration wastes will be returned to the activated alumina system over a four day period as before.

Waste from the final regeneration step of rinsing and adjusting the bed pH is held in a storage basin and blended over a four day period with the GAC effluent going to the activated alumina column. The supernatant from the chemical coagulation/precipitation treatment of the regeneration waste is blended over the same period. The total blended wastes plus GAC effluent is expected to have a fluoride level of 4.8 mg/l.

As discussed above, the selected design parameters are summarized in Table VI-1.

TABLE VI-1

FLUORIDE REMOVAL SYSTEM DESIGN PARAMETERS

Fluoride level - GAC effluent	3.7 mg/l
Fluoride level - GAC effluent blended with waste from regeneration	4.8 mg/l
Total flow to treatment plant	150-450 gpm
Maximum flow to one column	235 gpm
Minimum flow to one column	80 gpm
Maximum hydraulic loading	7 gpm/ft^2
Maximum superficial velocity	0.95 ft/min
Minimum retention time	5.3 min

TABLE VI-1

FLUORIDE REMOVAL SYSTEM DESIGN PARAMETERS
(Continued)

Diameter of column	6.5 ft
Bed depth	5.0 ft

Based on these design parameters, a three vessel fluoride removal system was selected. This treatment system utilizes two parallel beds to treat the entire flow up to a maximum of 150 gpm. A portion of the GAC effluent is slipstreamed and mixed with the column effluent when the flow is between 150 and 450 gpm. The treated effluent fluoride level varies from 0 to 1.6 mg/l when 150 gpm or less is treated. For flows above 150 gpm the effluent fluoride level will be fixed at 2.2 mg/l using the variable slipstream to maintain a constant effluent fluoride concentration.

When 150 gpm is treated, a column is regenerated every five days; when 450 gpm is treated, each column operates six days before being regenerated; one column will be regenerated and the waste stored and the next day the second column is regenerated. The waste from regenerating both columns is treated upon completion of the regeneration of the second column. See Tables VI-3 and VI-4 for the regeneration times and flows.

The column underdrain system and piping is sized for a flow of 235 gpm to allow half the maximum GAC effluent flow, in addition to the treated regeneration waste, to pass through each column. This will provide for flexible operation should the fluoride level in the raw water vary substantially from the expected 3.7 mg/l.

The sidewall depth of each column is 10 feet to provide for adequate bed expansion during backwash. The bed expansion during backwash ensures disengagement and removal of any suspended solids. Tanks for the alumina columns are constructed of steel with rubber linings and PVC internals to meet the ASME design code for 125 psig. The operating pressure of the column is 25 to 30 psig.

For the selected maximum downflow hydraulic loading of 7 gpm/ft^2 a theoretical head loss of 22 feet was determined. This includes allowance for head loss due to the shape of the top and bottom of the vessels, the flow distribution system inside the columns, and the underdrain system. The head loss through the bed during the 7.5 gpm/ft^2 upflow backwash is estimated to be 7 feet. Total head loss, including the head loss through the underdrain orifices, gravel layer, friction and minor losses in underdrain channels and piping, and elevation differences to the top edge of the washwater gutter, is about 18 feet.

The purpose of backwashing is to clean the accumulated suspended solids from the columns, and to expand the beds to rearrange the orientation of the alumina particles in order to minimize channeling. The object of regeneration is to remove all of the adsorbed fluoride from the bed before the units are returned to the treatment mode.

Regeneration is accomplished by treating the exhausted bed with a one percent solution of sodium hydroxide followed by a water rinse to flush the bed. The bed pH is then adjusted by a dilute solution of sulfuric acid and rinsed with raw water before being returned to operation. Details of the order of backwash-regeneration cycles are listed below.

TABLE VI-2

SINGLE ACTIVATED ALUMINA BED REGENERATION SEQUENCE

Cycle	Type of Water	Flow Direction	No. of Bed Volumes	Flow Rate gpm	Volume Water gal	Chemicals Used	Time min.
1	GAC effluent	Upflow	3.0	250	3,750	None	15
2	Soft	Upflow	4.1	85	5,100	1%NaOH	60
3	Soft	Upflow	8.2	170	10,200	None	60
4	Drain liquid to top of column						
5	Soft	Downflow	4.1	85	5,100	1%NaOH	60
6	Soft	Downflow	8.2	170	10,200	None	60
7	Drain liquid to top of column						
8	AA effluent	Downflow	24.7	170	30,600	H_2SO_4	180
Total			52.3		54,750		435 (7.25 hrs)

During regeneration of the activated alumina columns, the pH of the bed is raised to about 12 in order to solubilize the fluoride. This allows the fluoride to be washed out of the column. The raw water being treated has a hardness of 300 to 400 mg/l. If raw water was used for regeneration of the column bed, calcium carbonate and magnesium hydroxide would precipitate out at the high pH values. This precipitate would reduce the regeneration efficiency and tend to plug up the alumina bed. Therefore, softened water must be used for regeneration. Both the upflow and downflow rinses following the regeneration cycles will be more efficient in removing fluoride if soft water is used. The bed pH will still be high enough during the first hour of each rinse to cause

precipitation to occur if raw water is used. However, the bed pH is adjusted to 5.5 in the final three hour rinse and raw water can be used. The raw water pH is reduced to 2.5 during the first portion of this rinse, and at this pH the calcium and magnesium are soluble. Contact of this water with the bed does not change the pH sufficiently to cause precipitation during the final rinse.

Softened water is used for the regeneration Cycles 2 through 6 and raw water is used for the backwash, Cycle 1, and the final rinse and bed pH adjustment, Cycle 8. The one percent caustic solution for regeneration is prepared by inline mixing of commercial 50 percent sodium hydroxide with softened water. The sulfuric acid rinse and bed pH adjustment rinses are prepared using 93 percent, 66 degree Baume' sulfuric acid. After one hour of bed rinse using softened water, Cycle 8 is initiated where the soft water rinse stops and raw water is used for a final three hour rinse. The purpose of this final rinse is to adjust the pH of the column bed to near neutral for later use. During the three hour rinse with raw water, the pH of the rinse water is initially set at 2.5 and maintained there until the column effluent pH has been reduced to 6.5. Then the raw water rinse is adjusted to a pH of 5.5 for the remainder of the rinse cycle.

Pilot plant data indicate that the final rinse requires about three hours to wash the last of the fluoride out of the bed and adjust the bed pH to near neutral, suitable for storage. However, this cycle time can be varied as required.

The wastewater from the backwash is filtered and returned to the activated alumina influent wet well. The waste from Cycles 2 through 7

is sent to a precipitation basin for chemical coagulation/precipitation of the fluoride. The supernatant from this treatment, with a fluoride concentration of about 32 mg/l, is filtered and returned to the activated alumina system influent wet well over a four day period. See Section C.2 for further details. The waste from Cycle 8 is sent to the rinse holding basin and returned to the activated alumina influent wet well over the same four day period. The fluoride level during this four day period of treating the wastes blended with raw water is expected to be 4.8 mg/l.

These wastes will increase the fluoride concentration entering the column from 3.7 mg/l to 4.8 mg/l and the flow will increase by 10 gpm for each column regenerated during these four days if 150 gpm of GAC effluent is being treated. Each column will operate for seven days and require regeneration on the eighth day. The expected flows and fluoride levels are shown in Table VI-3. One column receives all the GAC effluent for about two days; the other column is regenerated during this period. During the remainder of the run both columns are operated in parallel. The flows and calculated fluoride concentrations for treating 450 gpm of GAC effluent are shown in Table VI-4. The GAC effluent to be bypassed via the slipstream varies from 0 to 266 gpm in order to maintain the total effluent at 2.2 mg/l fluoride.

TABLE VI-3

SYSTEM OPERATION TO TREAT 150 GPM

Day	Column 1		Column 2	
	Flow, gpm	Fluoride, mg/l	Flow, gpm	Fluoride, mg/l
1	80[(1)]	0	80	2.6
2	80	0	80	3.1
3	160	0.4	Regenerate	
4	160	1.4	No Flow	
5	80	1.9	80	0
6	80	2.4	80	0
7	80	2.9	80	0
8	Regenerate		150[(2)]	0.6
9	No Flow		160	1.6
10	80	0	80	2.1

(1) Treated regeneration waste being recycled, total flow = 160 gpm.

(2) No waste being recycled, total flow = 150 gpm.

TABLE VI-4

SYSTEM OPERATION TO TREAT 450 GPM

Day	By-Pass gpm	Column 1 Flow gpm,	Column 1 Fluoride mg/l (1)	Column 2 Flow gpm,	Column 2 Fluoride mg/l (1)	Column 3 (2) Flow gpm,	Column 3 (2) Fluoride mg/l (1)
1	266	92	0	Regenerate		92	0
2	234	118	0	-	-	118	0.2
3	216	127	0.2	-	-	127	0.8
4	174	148	1.0	-	-	148	1.7
5	39	215	2.3	-	-	215	3.0
6	128	161	3.1	161	0	Regenerate	
7	266	Regenerate		92	0	92	0
8	234	-	-	118	0.2	118	0
9	216	-	-	127	1.0	127	0.2
10	164	-	-	153	1.9	153	1.1
11	0	-	-	235	3.1	235	2.3
12	156	147	0	Regenerate		147	3.1
13	266	92	0	92	0	Regenerate	

(1) Fluoride concentrations are maximum fluoride at end of day.

(2) Column on Day 1 has been operated for 24 hours prior to Day 1.

C. WASTE DISPOSAL.

1. Alternative Processes. The fluoride removal process wastes come from two sources: regeneration of the alumina columns and regeneration of the water softener. Wastes from the alumina columns include sodium hydroxide and sulfuric acid used in the regeneration of the alumina media. These wastes have a high fluoride content (100 - 125 mg/l). The softener regeneration waste contains high sodium and calcium chloride levels. The need for a softened water supply was addressed in Section B.2, and therefore will not be discussed here. Table VI-5 lists the waste volumes of the chemical regenerant solutions.

TABLE VI-5

ALUMINA REGENERATION WASTE VOLUMES REQUIRING TREATMENT

Solution	Gallons per Regeneration
Raw water backwash	3,750 (1)
1 percent NaOH	10,200
Soft water rinse	20,400
Bed neutralization waste	30,600 (2)
Softener waste brine	2,400
Total	33,000

(1) Backwash is filtered and recycled to the fluoride removal system influent wet well and is not included in the total.

(2) Bed neutralization waste does not require chemical treatment prior to recycle and is not included in the total.

A presentation at RMA on February 28 and 29, 1980 outlined the results of an evaluation of three alternatives for the disposal of regenerant wastes from the activated alumina system. The alternatives

were evaluated based on their overall capital, operation, and maintenance costs; operational complexity; land and chemical requirements; and ultimate sludge disposal considerations. The following paragraphs summarize the three alternatives and their relative advantages/disadvantages.

a. Solar Evaporation Facility. Solar evaporation has proved to be a relatively effective and inexpensive method of treating wastes, providing that land is available at a reasonable cost. Based on a net yearly evaporation rate of 26 inches per year in the Denver area, a 4.5 acre surface area would be required for optimum evaporation of regeneration waste. A chlorinated polyethylene (CPE) liner with a thickness of 36 mils, in addition to an impermeable clay sublayer, would be utilized to prevent any seepage of evaporation facility contents into subsurface aquifers. A perforated PVC underdrain system would be placed between the liner and the clay layer to facilitate constant monitoring of liner integrity and to permit collection and analysis of any seepage. Solids accumulation over a 20 year period would be negligible.

The major advantages associated with a solar evaporation facility are the reduction in operational complexity and the relatively low annual operation and maintenance costs. The major disadvantage is system water losses due to evaporation (typically 3 to 4 percent of total plant production).

b. Chemical Treatment/Solar Evaporation. A second alternative would utilize chemical coagulation and precipitation of the fluoride present in the regeneration waste. The coagulation/precipitation reaction would take place in a batch precipitation basin, and the sludge

produced during the reaction would be pumped to a holding facility outside the treatment building. Sludge would then consolidate further, and water released during consolidation would be evaporated. Ultimate disposal of sludge would consist of chemical fixation and disposal at a site to be determined by the user.

The precipitation basin would be provided with rapid mix equipment for complete chemical dispersion throughout the basin. An additional holding basin would be required for storage of alumina bed rinse/neutralization flows to permit recycle over a three to four day period. The sludge holding/evaporation basin would require a 0.5 acre surface area for optimum evaporation of the water released during sludge thickening. The basin would be of concrete construction, with a CPE liner and an impervious clay sublayer. A perforated PVC underdrain system would be utilized to permit constant monitoring of liner integrity.

The chemical treatment/solar evaporation alternative would permit recycling the majority of the treated regeneration waste to the head of the fluoride removal system, therefore, water losses attributable to evaporation could be reduced. However, operational demands for this system would be considerably higher than those associated with the solar evaporation facility (alternative a). Annual maintenance and chemical requirements would also be substantially higher than for the solar evaporation facility alternative.

c. Chemical Treatment/Mechanical Sludge Dewatering. A third alternative would utilize a chemical coagulation/precipitation system identical to that described under alternative b. above. However, mechanical sludge dewatering would be utilized in place of the sludge holding/evaporation facility.

A continuous-discharge horizontal scroll centrifuge would be specified. Centrate would be returned to the treatment stream to minimize system water losses. To provide a centrifuge feed of relatively uniform solids concentration, a small sludge holding/mixing basin would be included. Chemical sludge from the precipitation basin would be pumped to the sludge holding basin, where the solids would be held in suspension by mechanical mixing. Dewatered sludge would be stored in drums and disposed of at a site to be determined by the user.

Advantages associated with the chemical treatment/mechanical sludge dewatering alternative include minimal system water losses and substantial reduction of sludge volume. Operational demands for this alternative would be greater than for alternative a. or b. due to the labor-intensive nature of the centrifuge dewatering system. Annual maintenance and chemical requirements would also be substantially higher than for the preceding alternatives.

d. <u>Evaluation of Alternatives</u>. Capital cost and annual operation and maintenance cost estimates were developed for each of the three alternatives. Life-cycle costs (capital costs annualized over 20 years plus annual operating costs) were also determined. These cost estimates are summarized in Table VI-6.

TABLE VI-6

WASTE DISPOSAL ALTERNATIVE COST ESTIMATES

	Solar Evaporation	Precipitation, Solar Evaporation	Precipitation, Mechanical Dewatering
Capital Cost	$665,853	$571,545	$559,399
Annual O&M Cost	6,235	28,447	34,782
Life-Cycle Cost	84,446	95,581	100,489

Based on the evaluation of the three alternatives, the A-E recommended that the solar evaporation facility be utilized for disposal of fluoride removal system regenerant wastes. However, in accordance with RMA recommendations and by COE directive, the chemical precipitation/ mechanical sludge dewatering system was selected for implementation at RMA.

Following the selection of the chemical precipitation/mechanical sludge dewatering alternative, an additional alternative for dewatering of sludge formed during the chemical coagulation/precipitation process was evaluated. This alternative would utilize the chemical coagulation/ precipitation system identical to that described under alternative b. "Chemical Treatment/ Solar Evaporation". However, a gravity sludge dewatering process consisting of a wedgewire filter bed system would be utilized in place of the sludge holding/evaporation facility.

The wedgewire filter bed system would consist of two beds, each sized for optimum dewatering of sludge produced during the chemical coagulation/ precipitation reaction. A polymer feed system would be included to properly condition the sludge prior to dewatering. Dewatered sludge removal from the filter bed would be done manually and

the sludge would be stored in suitable containers and disposed of at a site to be determined by the user.

Advantages associated with the chemical treatment/gravity sludge dewatering include low system water losses and significant sludge volume reductions. Operational demands for this alternative would be greater than for alternative a. or b. due to the more labor-intensive nature of the gravity sludge dewatering/disposal system. However, the greater operational reliability of the gravity dewatering system, as compared to the mechanical dewatering system (alternative c.), would make this a more attractive alternative. Significant annual operational cost savings would also be realized because of the low power consumption of the gravity sludge dewatering system.

To substantiate the manufacturer's claims concerning operational costs and sludge dewatering capabilities of the wedgewire filter bed system, the system was pilot-tested by both the A-E and by RMA personnel. The sludge utilized by the A-E in the pilot study was lime softening sludge from a local water treatment facility. Discussions with RMA personnel indicated that the calcium fluoride/calcium carbonate sludge formed during chemical treatment of the alumina regeneration waste would probably have settling and dewatering characteristics similar to lime softening sludge. While this sludge may not correspond exactly to the regeneration waste, it was considered to provide a general indication of the applicability and efficiency of the dewatering process.

A series of jar tests was conducted to determine optimum polymer types and dosages to obtain a thick, easily dewatered sludge floc. Three high molecular weight polymers (anoinic, cationic, and nonionic)

were evaluated. Based on this evaluation, anionic polymer at a dosage of 100 mg/l was selected for use in the sludge dewatering tests.

Pilot testing was conducted with a one square foot wedgewire screen unit. Approximately 5 gallons of softening sludge was used for each of the two test runs. Initial sludge solids content for the first test was 20 percent. For the second test, the sludge was thinned to a solids content of 5 percent to more closely approximate the characteristics of the full-scale chemical coagulation/precipitation process sludge. Both sludges were mixed with the appropriate polymer dosage and applied to the filter to a depth of 8 inches. After initial draining, sludge samples were extracted at one day intervals to monitor sludge consolidation characteristics. Solids content for both sludges after the initial 24-hour dewatering period was approximately 36 percent. After an additional 24 hours of dewatering, the solids content increased to approximately 40 percent and did not increase significantly after this period. Although the dewatered sludge still contained some entrained water that escaped during handling, it was a very workable cake that was easily removed from the filter screen. Filtrate suspended solids levels for both dewatering tests were below 50 mg/l.

Pilot tests conducted by RMA personnel on the actual alumina regeneration waste sludge also indicated that the wedgewire filter bed system could produce a workable, easily disposable sludge cake.

2. Selected Process. Based on an evaluation of the alternatives considered, the A-E recommends that a solar evaporation facility be utilized for disposal of activated alumina regeneration wastes. However, because of other considerations, and at the request of RMA personnel and

by COE directive, the selected alternative is chemical treatment and gravity sludge dewatering with the wedgewire filter bed process.

a. Chemical Requirements. Studies were conducted by the U.S. Army Engineer Waterways Experiment Station (USAEWES) to investigate the efficiencies of several compounds in coagulating and precipitating fluorides in the regeneration waste. The report on these studies ("Treatment and Disposal of Regeneration Wastewater from Activated Alumina Columns Used for Fluoride Removal from Ground Water at Rocky Mountain Arsenal", January 1980) evaluated lime, alum/polymer, and calcium chloride treatment on the basis of residual fluoride level after coagulation/precipitation as well as the process costs.

Based on an evaluation of these studies, alum/polymer addition was eliminated from further consideration because of the excessive chemical quantities required and the problems associated with handling and final disposal of alum sludge. Lime addition after waste neutralization was eliminated because of the possibility of fluoride resolubilization following settling of the precipitate formed during acid neutralization. This was experienced during the studies conducted by USAEWES. The probable removal mechanism for fluoride during neutralization may be adsorbtion onto the aluminum hydroxide precipitate formed during the reaction. The fluoride ions are eventually desorbed as the precipitate settles, and residual fluoride levels will increase accordingly. Therefore, immediate decanting of the waste following neutralization would be required prior to lime treatment. This method of operation would require a two-stage treatment process, and capital and operating costs would be increased significantly.

The selected chemical treatment system utilizes calcium chloride addition and pH adjustment to reduce fluoride levels in the regeneration waste. The calcium fluoride precipitate formed during the reaction of calcium chloride and fluoride is a very stable, insoluble compound. Once formed, calcium fluoride does not ionize in water, and therefore could be easily and safely disposed of. To facilitate maximum fluoride removal, the regeneration waste is neutralized with sulfuric acid to a pH of approximately 6.5 immediately following calcium chloride addition. This step permits additional fluoride removal through aluminum hydroxide precipitation/adsorbtion.

The USAEWES studies indicated that approximately 400 to 700 mg/l of $CaCl_2$ and 1,300 to 1,500 mg/l of H_2SO_4 would be required to reduce residual fluoride levels in the treated waste to approximately 30 to 35 mg/l. However, because of uncertainties in scale-up of jar test results, and differences between bench-scale and full-scale facility kinetics, sufficient chemical feed capacity is provided to permit plant operators to add significantly greater quantities of chemicals than those specified in the USAEWES report.

b. Precipitation Basin. A lined concrete precipitation basin is utilized for coagulation and precipitation of the regeneration waste. The basin has treatment capacity for two complete regeneration waste volumes. A 30 foot diameter basin, with 14.5 foot sidewater depth and a 2 foot freeboard allowance provides the required treatment volume. The basin is lined with fiberglass reinforced epoxy and baffled to facilitate complete mixing and prevent vortexing. Basin equipment includes an influent distribution weir, two 75 horsepower bridge-mounted rapid

mixers, and a rotating sludge collection system for removal of the precipitated solids. A decant mechanism consisting of a flotation supported flexible hose is included to provide an adjustable draw-off point for recycling of reactor supernatant. Chemical addition points are located above each rapid mixer to facilitate complete dispersion of H_2SO_4 and $CaCl_2$ throughout the basin.

Sludge formed during the precipitation reaction is collected by the rotating sludge collection system and directed to a central sludge pit for pumping to the gravity dewatering filter bed.

c. Rinse Holding Basin. A lined concrete basin is utilized to hold the waste from the final neutralization of the alumina beds prior to recycle to the plant influent wet well. The basin is unequipped except for the recycle pump suction.

d. Pressure Filters. To remove suspended solids from alumina column backwash, dewater sludge filtrate, and precipitation basin decant flows prior to recycle, two 5 foot diameter pressure filters are provided. One filter is utilized for filtration of the recycle flows, while the second filter functions as a standby. The filters are sized for a maximum solids loading of 1 pound suspended solids per square foot of media area. Mixed media (coal/sand/garnet) is specified because of its high surface area per unit volume, resistance to breakthrough, and high solids storage capability. Total media depth is 36 inches, and a media surface wash system is utilized to provide maximum solids removal during backwash.

To permit solids removal from the system, a 70 foot diameter evaporation basin is provided outside the treatment building. Filter backwash

is discharged to the basin once per month. The basin is sized for a net annual evaporation rate of 26 inches and with storage capability for five consecutive years of low net evaporation.

Provisions for discharge of filter backwash to the sludge sump at the head of the existing GAC plant, or the filter backwash evaporation basin are included for operational flexibility.

e. Sludge Dewatering/Disposal. Gravity sludge dewatering is utilized to reduce the sludge volume prior to disposal. Two 8-foot by 25-foot wedgewire filter beds are employed. Sludge formed during chemical treatment of two complete regeneration waste volumes is applied to one of the filter beds; the second bed serves as a standby. A conditioning tank is included for mixing polymer with the sludge pumped from the precipitation basin. The incoming sludge flows over a weir where it is sprayed with polymer. The conditioned sludge then flows by gravity to the filter bed. The polymer system is designed for use with either liquid or dry polymer.

Based on the results of the RMA sludge dewatering pilot testing, the sludge produced by the wedgewire filter beds can be easily handled during container filling operations. Provisions are made for discharging filtrate to the pressure filter influent, the sludge sump at the head of the existing GAC plant, the precipitation basin, the filter backwash evaporation basin, or directly to the fluoride removal system influent wet well. With proper dewatering system operation, filtrate suspended solids levels are expected to be considerably below 50 mg/l, which permits direct recycle to the fluoride removal system influent wet well.

Ultimate disposal of dewatered sludge consists of storage of the sludge-filled containers at a site to be determined by RMA personnel.

f. Waste Disposal System Operation. At the request of the user, and by a COE directive, the waste disposal control system is designed to require relatively continuous monitoring by plant operators during waste treatment operations. The following is a summary of waste disposal system operating sequences, with the required operator activity identified where appropriate.

Regeneration brine from the water softener is pumped to the precipitation basin as it is produced (approximately 2,400 gallons per regeneration). As the activated alumina regeneration cycle is initiated, the raw water backwash (Cycle 1, 3,750 gallons) is directed to the wash water storage tank. The plant operator sets the appropriate valves to direct subsequent waste flows (Cycles 2, 3, 5, and 6, 30,600 gallons) to the precipitation basin, where it is combined with the softener regeneration waste. (Cycles 4 and 7 drain to the building chemical sump.) Since some calcium fluoride/calcium carbonate sludge may be formed during the reaction of alumina regeneration waste with calcium present in the softener regeneration brine, the rotating sludge collection equipment starts automatically as regeneration waste begins to flow into the basin. The operator adjusts the appropriate valves to direct the first 2-hour bed neutralization flow (Cycle 8, 20,400 gallons) to the rinse holding basin. The final hour's flow (10,200 gallons), which has a low fluoride content, is directed to the fluoride removal system effluent wet well to be blended with alumina column effluent.

The above sequence is repeated for a second column regeneration before chemical treatment and recycle of the wastes. After the second column has been regenerated, the plant operator withdraws a sample from the precipitation basin and performs a jar test to determine the amounts of calcium chloride and sulfuric acid required to maximize calcium fluoride sludge formation and to neutralize the waste to a pH of 6.5. The basin rapid mix units are then put into operation, and the appropriate chemical quantities are added. The rapid mixers continue to operate until the chemicals and basin contents are completely mixed and are then shut down by the operator to permit settlement of calcium fluoride floc.

Recycle of the stored bed neutralization flows (40,800 gallons) is manually initiated by the operator. The wastes flow directly to the fluoride removal system influent wet well, and the recycle pumping system is designed to permit return of the rinse holding basin contents over a four day period.

The plant operator is required to analyze the residual fluoride level of the precipitation basin contents prior to initiation of the decant/recycle step. If the fluoride level is within acceptable limits (30 to 35 mg/l fluoride), and the calcium fluoride floc has settled sufficiently, the operator initiates the decant return operation. The precipitation basin supernatant is then filtered and recycled to the fluoride removal system influent wet well over a four day period. Provisions for bypassing the filters are included to permit direct recycle of treated regeneration wastes that are low in suspended solids content. During initial startup of the waste disposal system, the

operator will be required to preset the minimum supernatant decant level. The correct level setting is an important factor in preventing high filter solids loadings, and is based on the height of the calcium fluoride sludge blanket after settlement.

The operator is also required to manually initiate the filtration and recycle of the stored alumina backwash flow to the fluoride removal system influent wet well. The pressure filter requires backwashing after each precipiation/recycle operation. Backwash is manually initiated by the plant operator; however, all backwash operations are controlled automatically by preset timers. The operator sets the appropriate valves to direct the backwash flow to the sludge sump at the head of the existing GAC plant, the precipitation basin, or to the evaporation basin.

Before starting the sludge dewatering process, the operater is required to add "support water" from the nonpotable water system to the wedgewire filter bed until it reaches a depth of approximately 1/2-inch above the filter panels. This support water facilitates distribution of the incoming sludge over the entire screen area, and also prevents screen "blinding" due to rapid initial extraction of sludge fluid.

The sludge formed during the precipitation reaction is then pumped from the central collection pit to the sludge conditioning equipment. Polymer is mixed with the incoming sludge to produce a dense, easily dewatered floc. The plant operator will need to monitor polymer solution levels and consumption both prior to and during sludge conditioning

to insure that an adequate supply is available for conditioning the entire sludge quantity.

The conditioned sludge then flows onto the wedgewire screen. Solids may accumulate in the area of the influent sludge line, and the operator may be required to remove these accumulations during filling to insure equal distribution of solids over the entire screen area. Any free water associated with the conditioned sludge drains through a sloped wedgewire panel at one end of the filter bed.

The operator then opens the screen drainage valve and adjusts the flow rate. As the optimum drainage rate is related to the sludge dewatering characteristics, the actual rate will be determined during initial plant operation. The drainage rate should be such that sludge porosity is maintained during draining, and slow enough to prevent rapid compression of the sludge layer which would plug screen openings. A flow rate which corresponds to a free water surface drop of 2 to 3 inches per hour should provide adequate sludge dewatering. The filtrate flows by gravity to the fluoride removal building sump. The operator then has the option of sending the filtrate to any of five locations. If the filtrate suspended solids levels are low (less than 50 ppm), the operator will direct the filtrate to the pressure filters for solids removal prior to recycle to the fluoride removal system influent wet well. The operator may also bypass the filters and recycle the filtrate directly to the wet well should solids levels permit. If filtrate suspended solids levels are high, the operator can direct the flow to the precipitation basin, the sludge sump in the existing GAC building, or to the filter backwash evaporation basin.

Water will continue to drain from the sludge for several hours after the initial draining of support water. During this period, the sludge will undergo compaction due to its own weight, and some additional dewatering will take place due to evaporation.

When the sludge has reached a consistency that permits it to be handled easily (typically 1 to 2 days), removal of the cake is initiated. Cake removal consists of hand-cleaning and filling the containers placed between the two screen units. Following cake removal, the containers will be removed and sent to the ultimate disposal site, and the screen will be hosed down to remove any accumulated solids.

Total fluoride removal system water losses (i.e., losses attributable to sludge removal and filter backwash evaporation) represent approximately 0.1 percent of total system treated water production (at 150 gpm plant flow).

D. IMPACTS ON THE EXISTING TREATMENT SYSTEM. The existing treatment units consist of two dual media filters for removal of suspended solids and two activated carbon adsorption towers for removal of organic contaminants. Currently, the plant is operated by passing flow through both filters in parallel and through one carbon column. In the carbon columns the organics removal is accomplished by transfer of the organic contaminants from the water to the surface of the granular activated carbon particles. The organic contaminants, including diisopropylmethylphosphonate (DIMP), dicyclopentadiene (DCPD), and organic sulfur compounds, are removed to levels lower than the limits recommended by the U.S. Army Surgeon General.

Anticipated maximum flow to the existing plant would be 450 gpm. Since the existing filters and carbon columns are not designed to handle this flow rate, additional facilities will be required.

One alternative for the recycling of pressure filter wash water and dewatered sludge filtrate is to return these flows to the existing GAC plant sludge sump. These recycle flows (filter wash water at 350 to 400 mg/l suspended solids, and filtrate of less than 50 mg/l suspended solids) will add to the amounts of sludge currently being sent to the sump for disposal. However, it is estimated that solids accumulation will not significantly increase present sludge disposal requirements.

The brine from the water softener regeneration is sent to the precipitation basin to be mixed with the activated alumina regeneration wastes (see Section C for additional details). This brine supplies part of the $CaCl_2$ required to precipitate the fluoride in the regeneration waste. The water softener brine and the additional $CaCl_2$ added to

complete the precipitation reaction increases the chloride concentration in the waste. This combined waste will be decanted, filtered, and pumped over a four day period to the activated alumina system influent wet well. Since nothing in the treatment system removes chloride, the chloride concentration in the reinjected water will increase by about 20 mg/l (based on a plant flow rate of 150 gpm). Based on a ground water chloride level of 350 mg/l (USAEWES study), this would represent an increase of approximately 5.7 percent. This increase is not expected to have any significant detrimental impact on the existing ground water quality.

E. SELECTED PROCESSES DESIGN CONSIDERATIONS.

1. Liquid Processes. The liquid processes are used for removing fluoride from ground water. The facilities employed include the wet well, influent pumps, activated alumina columns, backwash pumps, regeneration pumps, chemical feed and storage facilities, and the water softener system.

a. Wet Well. GAC plant effluent requiring fluoride removal is discharged to the influent wet well. A wet well is provided, rather than inline feed to the alumina columns, to minimize the effects of fluctuations in discharge pressure and flow rate from the GAC plant on the operation of the fluoride removal plant. The influent wet well is the return point for flows recycled from the waste treatment operations and is the source of column backwash water. The operation of the GAC plant is not affected by a temporary shutdown of the fluoride removal plant. The wet well is located as a substructure beneath the new building, which avoids outdoor location and associated maintenance problems with the influent and the alumina column backwash pumps. The wet well is vented, provided with manhole cover access and a high water level alarm. Since the plant is designed for continuous operator monitoring, it is expected that flow to this wet well will be manually stopped following a high water level alarm, and automatic overflow is not required. The wet well stores enough water for alumina column backwash, and is the suction pit for both the alumina columns influent and backwash pumps.

b. Influent Pumps. Three 150 gpm, 7.5 horsepower, variable speed vertical turbine pumps feed the alumina columns. The pumps provide sufficient head to discharge the treated water to the effluent wet well

and are designed for several expected modes of operation, including up to 150 gpm through one column, and 450 gpm to the plant with variable bypass. The use of variable speed pumps allows the flow rate of water requiring fluoride removal to be preset once at the GAC plant and thus results in a minimum amount of interfacing between the two plants. With an expected flow 110 to 150 gpm that requires fluoride removal, excess installed capacity is available. Should changes in ground water quality necessitate long term treatment of more than 300 gpm, consideration should be given to replacing some or all of the pumps with larger capacity units. Three pumps are provided, instead of two larger ones, to allow the pumps to run closer to maximum speed and the optimum efficiency point. To maintain a constant wet well water elevation during periods of varying GAC plant effluent flow, the pumps will operate between 77 percent and 100 percent of maximum speed.

c. Activated Alumina Columns. The activated alumina columns are skid mounted, rubber lined, steel pressure vessels, rated for 125 psi and bearing an ASME stamp. The front piping has been laid out by the A/E, but the specifications are written to allow the Contractor to submit different piping arrangements for approval. The front piping is polypropylene lined steel or ductile iron pipe, selected because of strength and durability. Although, fiberglass reinforced plastic (FRP) pipe is more readily available, it is susceptible to stresses caused by minor misalinements as well as to serious failure. The front piping and valves are specified to be shop assembled. Shop assembly requires a longer construction period, but eliminates many other problems. The

shop drawing process is quicker and easier; there is assurance that experienced personnel will design the piping and supports; one supplier is responsible for the performance of all this interrelated equipment, and his field representative can have greater authority to insure proper assembly. Field assembly would mean a potential reduction of several months in construction time, but is subject to other problems. There is the possibility that inexperienced personnel of the Contractor will be involved with erection; there is a greater chance that something will be overlooked or incomplete in the shop drawings, and the shop drawing review process will most likely be longer. If construction time is more critical than these other factors, field assembly can be substituted. The activated alumina media is specified to be unused and similar to the media used in the pilot plant studies.

d. Column Backwash Pumps. Two 250 gpm, 7-1/2 horsepower, constant speed vertical turbine pumps provide backwash water for the first step of alumina regeneration. A rate control valve allows the operator to increase the backwash rate slowly from 0 to 250 gpm to avoid media loss during bed expansion, and to hold the flow at 250 gpm as the wet well level varies. The controls are interlocked so that starting these pumps will lock out the influent pumps, allowing the backwash to be completed without interruption due to low wet well level. These pumps are located in the influent wet well.

e. Regeneration Pumps. Three constant speed, 85 gpm, 5 horsepower, vertical turbine pumps provide water for alumina column regeneration. These pumps are located in the effluent wet well, and supply

either 85 gpm or 170 gpm during various system conditions. Regeneration water must be supplied for the steps listed in Section B.2, Table VI-2. When the 170 gpm of softened water is supplied, two regeneration pumps will operate. When 85 gpm of softened water or 170 gpm of treated water (softener bypassed) is supplied, one regeneration pump will operate. Only one pump is required for the 170 gpm treated water flow because of the head loss reduction attributable to the softener bypass. The pump specification is written such that the supplied pumps will meet both of these conditions.

f. Chemical Feed and Storage. The liquid process requires the use of both sulfuric acid and sodium hydroxide. The sulfuric acid system consists of a 6,000 gallon outdoor storage tank, spill containment structure, day tank, and pumps. The day tank and pumps are located inside the building. The storage tank is located outside at the request of RMA and at the direction of the COE. This is against the recommendation of the A-E, who believes an indoor location is more suitable for this project. Sulfuric acid is also used in the treatment of regeneration waste as will be described in another section. Four concentrated acid feed pumps take suction through the bottom of the tank. Although bottom connections are generally avoided if possible due to corrosion problems, the maintenance associated with outside tank mounted pumps will offset any benefits derived from avoiding bottom connections. Thus, the outside tank location has resulted in a change in the type and location of acid pumps from tank mounted pumps with top connection to floor mounted pumps with a bottom connection.

The sodium hydroxide system consists of an indoor 6,000 gallon steel storage tank, spill containment structures, and four concentrated caustic soda pumps. Softened water is used to dilute concentrated sodium hydroxide. The expected dosage for effluent pH adjustment is 1.74 to 4.44 gal/hr of concentrated sodium hydroxide. The expected dosage for alumina regeneration is 68 gal/hr.

The calcium chloride feed system will be covered in the waste and sludge process section. Emergency showers are located outside near the tank fill stations and inside near the chemical pumps.

g. Water Softener System. The water softener system consists of two 85 gpm sodium cycle ion softeners, a brine mixing tank, and two brine pumps. Ion exchange softeners work best when operated continuously rather than in an on-off manner. Thus, when the required flow rate changes from 85 gpm to 170 gpm and back to 85 gpm as required for the regeneration steps listed in Table VI-2, it is not desirable to have a second softener come online to provide the additional flow. The suggested operation is to have two softeners continuously on line. When 85 gpm is required, the softeners would be piped and valved in series, with one regeneration pump running. When 170 gpm is required, the softeners would be valved in parallel with two regeneration pumps running. The regeneration pumps have been designed for the worst case, which is 85 gpm with softeners in series. A package system is specified, with all the components listed above and the instrumentation and controls required for automatic operation supplied by one manufacturer with the proper connections to be made to the plant control cabinet.

h. Instrumentation and Controls. The normal operation of the liquid processes is manual. The amount of influent to be bypassed will be manually adjusted. Normal expected operation will be to treat all water with no bypass. Putting columns on or off line and initiation of regeneration is done manually. Each step in the regeneration process is controlled by a pushbutton. The correct valves and pumps start, stop, or change position automatically based on the pushbutton signals. The length of each regeneration step is controlled by an adjustable timer with manual override. Each consecutive regeneration step must be initiated by the operator. The controls allow the operator to combine regeneration Steps 2 and 3 (also 5 and 6) into one continuous step. This permits less frequent starting and stopping of the regeneration pumps. The water softener controls are interlocked with regeneration controls so that the softeners are in the correct alinement (series or parallel) for each regeneration step.

Wet well level controls are provided in both the influent and effluent wet wells to automatically start and stop the pumps. The backwash pumps have priority over the influent pumps. Upon pushbutton initiation of column backwash, the influent pumps are "locked out" to allow completion of backwash without interruption due to the wet well level. The level controls in the effluent storage wet well are set so that the regeneration pumps and filter backwash pumps have priority over the recharge pumps.

i. Piping Materials. The specifications allow the Contractor options on piping materials as much as possible. Whenever the liquid is corrosive or aggressive (e.g., softened water), the choices will be

limited to polypropylene lined steel, ductile iron, or fiberglass reinforced plastic (FRP) pipe, except that FRP pipe will not be allowed for shop assembled alumina column piping. Whenever the liquid is not corrosive or aggressive, the Contractor will have the option of cement mortar lined cast iron, ductile iron or steel, or FRP in suspended pipe. Exterior buried pipe may also be Schedule 80 polyvinyl chloride (PVC). Asbestos cement pipe and reinforced concrete pipe are not allowed due to questionable suitability for this service and uncertain availability in smaller sizes.

2. Waste and Sludge Processes. The waste processes involve receiving the regeneration and water softener wastes and treating or recycling these wastes. The sludge processes involve collecting, thickening, and disposing of solids in the treated waste. The facilities include the precipitation basin, rinse holding basin, sludge pumping, pressure filter and recycle pumping, sludge dewatering equipment, pressure filters, evaporation basin, chemical feed equipment and instrumentation and controls.

a. Precipitation Basin. Regeneration wastes from Steps 2, 3, 5, and 6 are discharged to the precipitation basin. The basin is sized to hold the waste from two regenerations plus the water softener waste brine, a total volume of 66,000 gallons, plus an additional 2 feet of storage. This 2 feet of storage gives the operator some flexibility in the sludge dewatering process. The dimensions of the reinforced concrete basin are 30 feet-0 inch inside diameter by 14 feet-6 inches sidewater depth with 2 feet-0 inch freeboard. The water depth of 14 feet-6 inches was chosen for mixing efficiency. The top of the concrete

wall is set at Elevation 108.50, which is as high as possible inside the chosen building. This allows the basin to withstand ground water uplift without the use of foundation drains or pressure relief valves. The bottom is sloped 1/4 inch in 12 inches to provide drainage. The basin is equipped with beam supported circular sludge collecting equipment. Special materials or coatings for submerged parts and concrete to withstand high pH levels and calcium fluoride sludge are specified. The concrete coating is fiberglass reinforced epoxy. The equipment supplier will provide the sludge scraper and 1/2 horsepower drive, support beams, walkway, ladder, and rapid mixers. An additional equipment item will be a variable level decant mechanism. The two 75 horsepower rapid mixers are sized for complete mixing of chemicals with the basin contents. Baffles are provided to prevent vortexing and are fabricated from redwood boards. The basin design provides for all sludge to be moved to a central hopper that serves as the sludge pump suction pit.

Several features of the design have resulted from meetings between the A/E, COE, and RMA. RMA indicated that flocculators are not needed and requested that they not be provided. RMA also requested that only one basin be equipped for precipitation. Thus, the rinse holding basin is not equipped to serve as a backup to the precipitation basin.

b. <u>Rinse Holding Basin</u>. The first two hours' waste from the final rinse step of the regeneration process is stored in the rinse holding basin. The basin is sized to hold the waste from two regenerations, a volume of 40,800 gallons. The dimensions of the reinforced concrete basin are 25-foot diameter by 12-foot sidewall depth, which provides approximately 12 inches of freeboard. The concrete is coated

with fiberglass reinforced epoxy to withstand the high pH conditions. The top elevation of the concrete wall is 105.00 feet. The bottom slopes 1/4 inch in 12 inches to provide for drainage, and a small center hopper is provided for pump suction.

c. Sludge Pumping. Two progressing cavity pumps are provided to remove sludge from the precipitation basin and discharge through the conditioning tank to the filter beds. Progressing cavity pumps were selected since the sludge characteristics are not well known. The percent solids, abrasiveness, and flowability have not been established in a full scale plant. Nonclog centrifugal pumps may possibly be suitable for this sludge, but could not be selected because of the incomplete information on sludge characteristics. The pumps are sized to provide the flow recommended by the filter bed manufacturer with one pump being an installed spare, and are rated for 50 gpm at 5.5 feet head. Two horsepower motors are provided. A sludge pumping dry pit is provided to virtually eliminate suction lift and to provide more efficient basin dewatering. The pump intervals are specified to be compatible with a calcium fluoride sludge and softened water. The suction and discharge piping is also specified for softened water service (See Section 1.i. above). Tees with blind flanges are provided to allow cleanout of the pipe without disassembly.

d. Washwater Holding Tank. A reinforced fiberglass plastic tank is provided to store the alumina column backwash water, which will be filtered and returned to the fluoride removal plant influent wet well. The nominal tank volume is 7,500 gallons, which provides storage for two backwash cycles.

e. Chemical Feed and Storage. Calcium chloride, sulfuric acid, and polymer are provided for the waste and sludge processes. Caustic soda is discussed in Section 1.f., as is a description of the sulfuric acid system. The calcium chloride system consists of a 6,000-gallon steel storage tank, spill containment structure, and two concentrated $CaCl_2$ metering pumps, all located indoors. The feed rate is 10 to 11 gpm of concentrated $CaCl_2$ for 10 to 15 minutes.

The polymer system consists of two tanks with blending funnel and mixer, and two metering pumps. The small amount of polymer needed requires only a small storage area for either bags or drums. The feed rate is 2.5 lb/hour.

The acid is fed to the precipitation basin from a 100-gallon steel day tank mounted above the basin. This tank is fed by a concentrated acid metering pump controlled by a timer. Feed into the basin is manually controlled from the day tank, and should be approximately 50 to 70 gallons per two regenerations. The use of the day tank mounted above the basin allows using an acid pump of the same size as the other metering pumps, thus reducing the number of spare pumps required.

f. Return Pumping. The precipitation basin decant, the first 2-hour final rinse, and the alumina column backwash water are recycled within the fluoride removal plant using three single-stage horizontal turbine pumps. One pump feeds the pressure filters with decant and/or column backwash and discharges to the influent wet well. The piping is also arranged to pump the wedgewire filter bed filtrate to the pressure filters. One pump is used to recycle the final rinse water to the influent wet well. The third pump is a spare, and is piped so that it

can serve as a standby for either of the other two. The pumps are rated at 10 gpm and have 1/2 horsepower motors. This allows these flows to be returned over a four day period at a total rate of 20 gpm. The filter pump and the installed spare are identical, and rated at a higher head than the recycle pump due to the pressure drop across the filters. Thus the spare pump must be throttled to maintain a 10 gpm flow rate when used to recycle final rinse water.

g. Sludge Dewatering. Two 8-foot by 25-foot filter beds are specified for sludge dewatering. The filter beds are located in the NE corner of the building and are supported directly on the building slab without equipment base, anchorage or grout. The filter beds will receive special field painting for resistance to softened water and calcium fluoride sludge. To enhance drying, 3-inch air connections are provided for possible future installation of an air blower. The filter beds drain to a central pit, which can be used for monitoring filtrate solids levels. The filtrate will drain to the building sumps, from which it can be discharged to the filter backwash evaporation basin, the GAC plant sludge sump, the precipitation basin, the influent wet well, or to the pressure filters.

h. Pressure Filters. The pressure filters are skid mounted package units. Operation is automatic with the operator initiating the mode of operation and the correct valves adjusting automatically. A 5-foot diameter filter requires 350 gpm for backwashing, which is provided by two vertical turbine pumps located in the effluent wet well. The pumps are 25 horsepower rated for 350 gpm at 16-foot head. One pump is an installed spare. The filter backwash water is discharged to either the evaporation basin or the GAC plant sludge sump.

i. Evaporation Basin. The filter backwash evaporation basin is 70 feet in diameter by a 5 foot-6 inch sidewall depth, and is constructed of reinforced concrete. The criteria used for sizing this basin are described in Section C.2.d.

j. Instrumentation and Control. Control of the waste and sludge processes is primarily manual. The valves controlling the discharge of regeneration waste are automatically operated as part of the regeneration process. Treatment of the wastes in the precipitation basin is manually controlled. The chemical feed pumps and rapid mixers have manual on-off controls. The sludge collecting equipment is interlocked with the regeneration controls so that it begins operation as soon as waste is discharged into the precipitation basin, but is manually stopped. The filters and recycle pumps are operated manually. Flow tubes and manual rate control valves are provided in the filter influent and recycle lines, since the discharge rate of these pumps is sensitive to static head. The sludge pumps are provided with on-off controls and with an adjustable timer than can be used to control the amount of sludge drawn off. All operations associated with the wedgewire filter beds are manually controlled.

All pumps and other mechanical equipment are provided with both local on-off controls and control panel or motor control center on-off controls. As much as is practical, the controls are centrally located in a control cabinet. This control cabinet, together with the motor control center, is located near the laboratory to provide a "focal point" of operation. Also, a plant flow panel is provided that gives a schematic picture of what equipment in the plant is operating.

CHAPTER VII

ACCESS DRIVE

A. ACCESS DRIVES.

Vehicular access to the southside of the fluoride building and to the acid storage tank is provided by a 12-foot wide aggregate paved drive. The geometry of this drive, coupled with the turn-in area just east of "D" Street, will permit access and egress to a semitrailer with a 40-foot wheelbase approaching from and departing to the south. Total compacted aggregate pavement thickness is 6 inches.

Vehicular access into the fluoride building is provided on the east side of the building. The turn-in area just east of "D" Street and the entrance drive into the building are designed to allow a midsize vehicle with a wheelbase of 16 feet to enter the building. Total compacted aggregate pavement thickness is 6 inches.

CHAPTER VIII

LIST OF SPECIFICATIONS

DIVISION 1 - GENERAL REQUIREMENTS

- 1A Special Provisions
- 1B Warranty of Construction
- 1C Environment Protection
- 1D Special Safety Requirements

DIVISION 2 - SITE WORK

- 2A Clearing and Grubbing for Roads and Structures
- 2B Excavation, Filling and Backfiling for Structures
- 2C Excavation, Trenching and Backfilling for Utilities Systems
- 2D Grading
- 2E Gravel Surfacing
- 2F Seeding

DIVISION 3 - CONCRETE

- 3A Concrete (For Building Construction)

DIVISION 4 - NOT USED

DIVISION 5 - METALS, STRUCTURAL AND MISCELLANEOUS

- 5A Miscellaneous Metal

DIVISION 6 - WOOD AND PLASTICS

- 6A Fiberglass Reinforced Plastic Tank
- 6B Fiberglass Reinforced Epoxy Lining
- 6C Chemical Sump Tank

DIVISION 7 - THERMAL AND MOISTURE PROTECTION

- 7A Calking and Sealants

DIVISION 13 - SPECIAL CONSTRUCTION (Cont'd)

13C Metal Buildings

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DIVISION 14 - CONVEYING SYSTEMS

14A Pallet Lift Truck

DIVISION 15 - MECHANICAL

15A Plumbing, General Purpose

15B Gas Fitting

15C Air-Conditioning System (Unitary Type)

15D Heating Systems, Direct Gas-Fired Units

15E Waterlines

15F Process Piping

15G Miscellaneous Process Piping

15H Identification of Piping

15J Pipe Supports

15K Miscellaneous Valves

15L Flow Tubes

15M Pumps, Water, Vertical Turbine

15N Pumps, Water, Horizontal Turbine

15P Pumps, Sludge, Progressing Cavity

15Q Chemical Feed Systems

15R Chemical Sump Pumps

15S Piping Schedule

DIVISION 16 - ELECTRICAL

16A Electrical Work, Interior

16B Electrical Work, Exterior

16B Lightning Protection System